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Miura et al.

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(54) **DETECTION DEVICE, LOAD CONTROL DEVICE, AND LOAD CONTROL SYSTEM**

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(58) **Field of Classification Search**
CPC G01J 1/4228; G01J 1/0266; G01J 1/0271
(Continued)

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Assistant Examiner — Meenakshi Sahu
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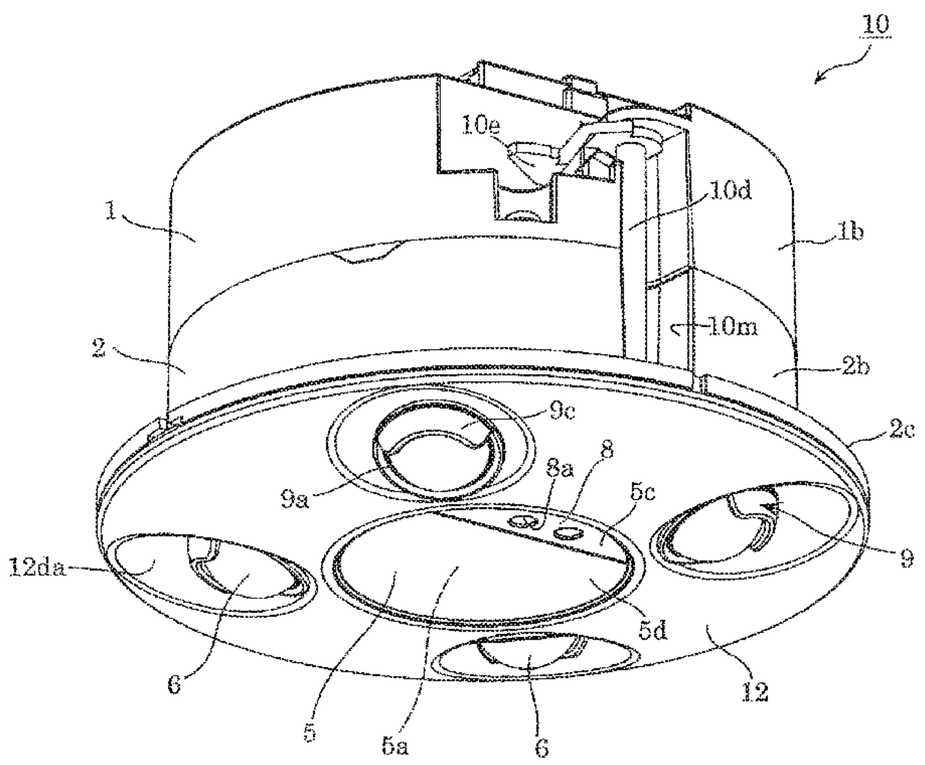
(57) **ABSTRACT**

A detection device includes: a first sensor which detects, based on a captured image, whether a person is present in a first detection range; a plurality of second sensors which are disposed around the first sensor, and detect, based on infrared radiation, whether a person is present in respective second detection ranges each of which overlaps at least a portion of the first detection range; and at least one hood which blocks part of infrared radiation directed to at least one of the plurality of second sensors, to reduce a non-overlapping portion of a combined detection range of the first detection range of the first sensor and the second detection ranges of the plurality of second sensors, the non-overlapping portion being a portion in which the first detection range and the second detection ranges do not overlap.

10 Claims, 12 Drawing Sheets



(51) **Int. Cl.**
G01J 1/02 (2006.01)
G01V 8/20 (2006.01)

(58) **Field of Classification Search**
USPC 250/338.1
See application file for complete search history.

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FIG. 1

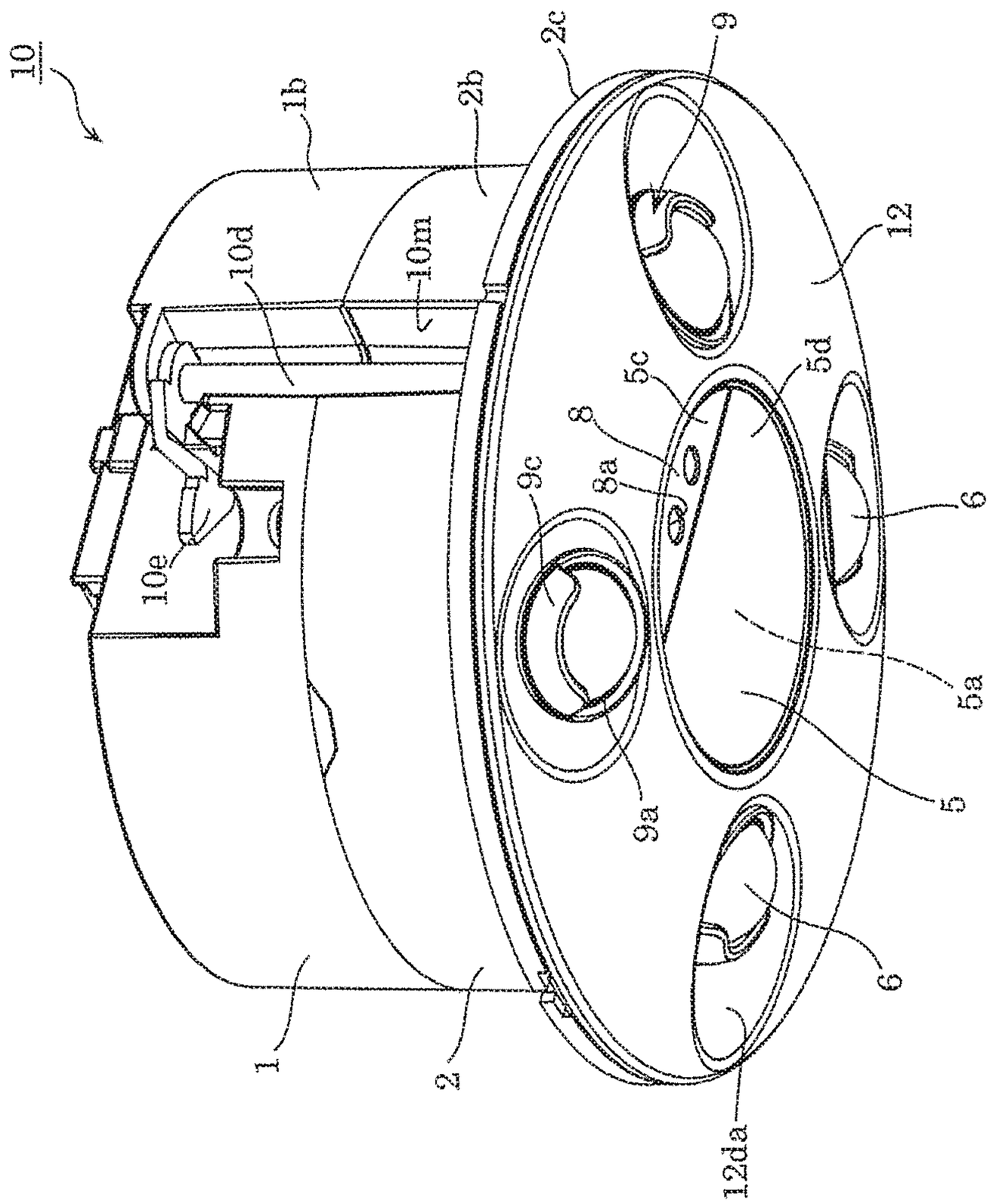
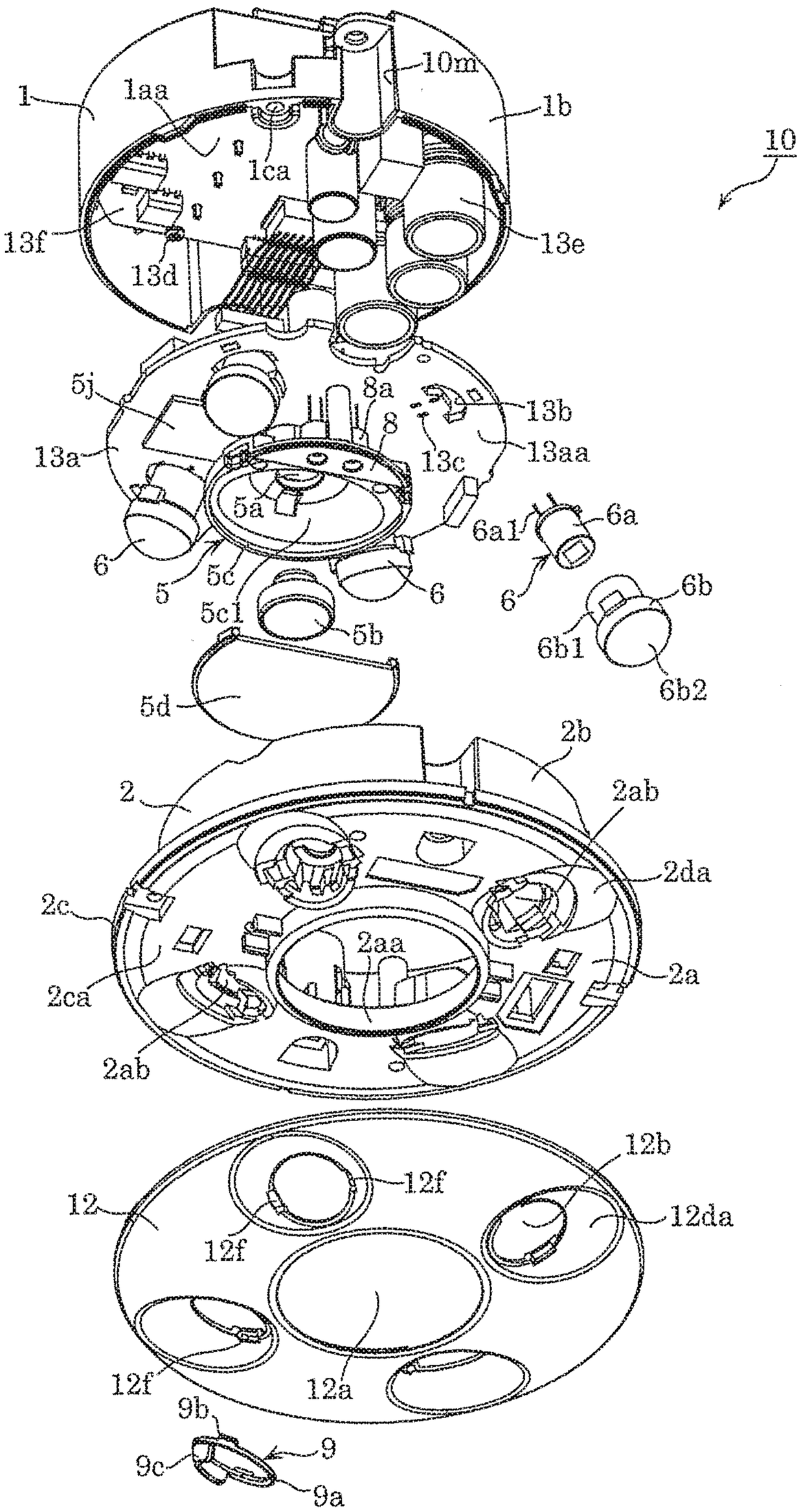


FIG. 2


10
1
1aa
10m
1b
1ca
13f
13d
13e
5j
8a
8
13b
13aa
13a
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5a
6a1
6a
6
5
5c
6
6
6b
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6b1
6b2
5d
2b
2
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2c
2aa
2a
2ca
2ab
12b
12f
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9b
9
9c
9a

FIG. 3

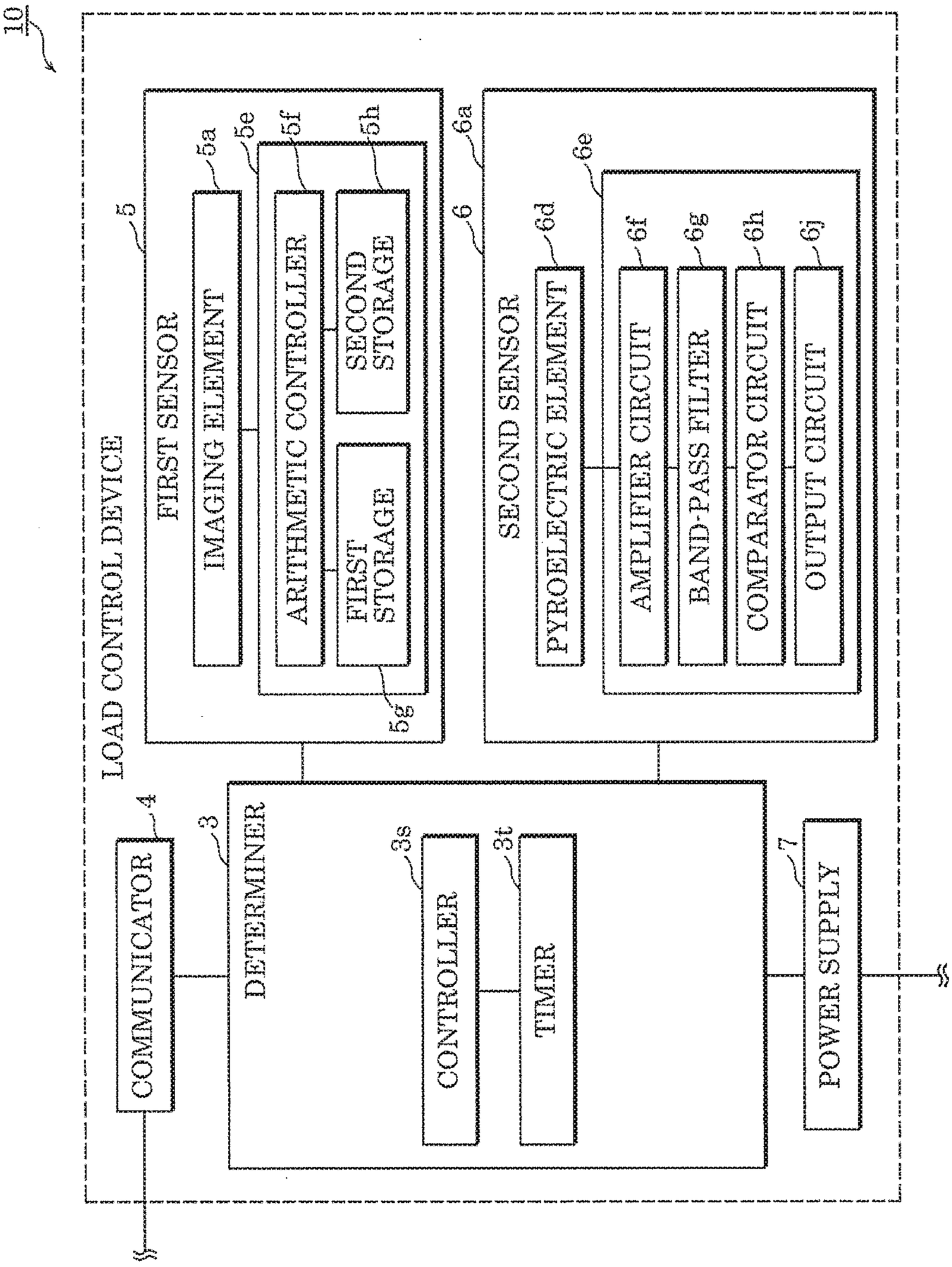

10
LOAD CONTROL DEVICE
5
FIRST SENSOR
5a
IMAGING ELEMENT
5e
ARITHMETIC CONTROLLER
5f
FIRST STORAGE
5h
SECOND STORAGE
5g
6
6a
SECOND SENSOR
6d
PYROELECTRIC ELEMENT
6e
6f
AMPLIFIER CIRCUIT
6g
BAND-PASS FILTER
6h
COMPARATOR CIRCUIT
6j
OUTPUT CIRCUIT
4
COMMUNICATOR
3
DETERMINER
3s
CONTROLLER
3t
TIMER
7
POWER SUPPLY

FIG. 4

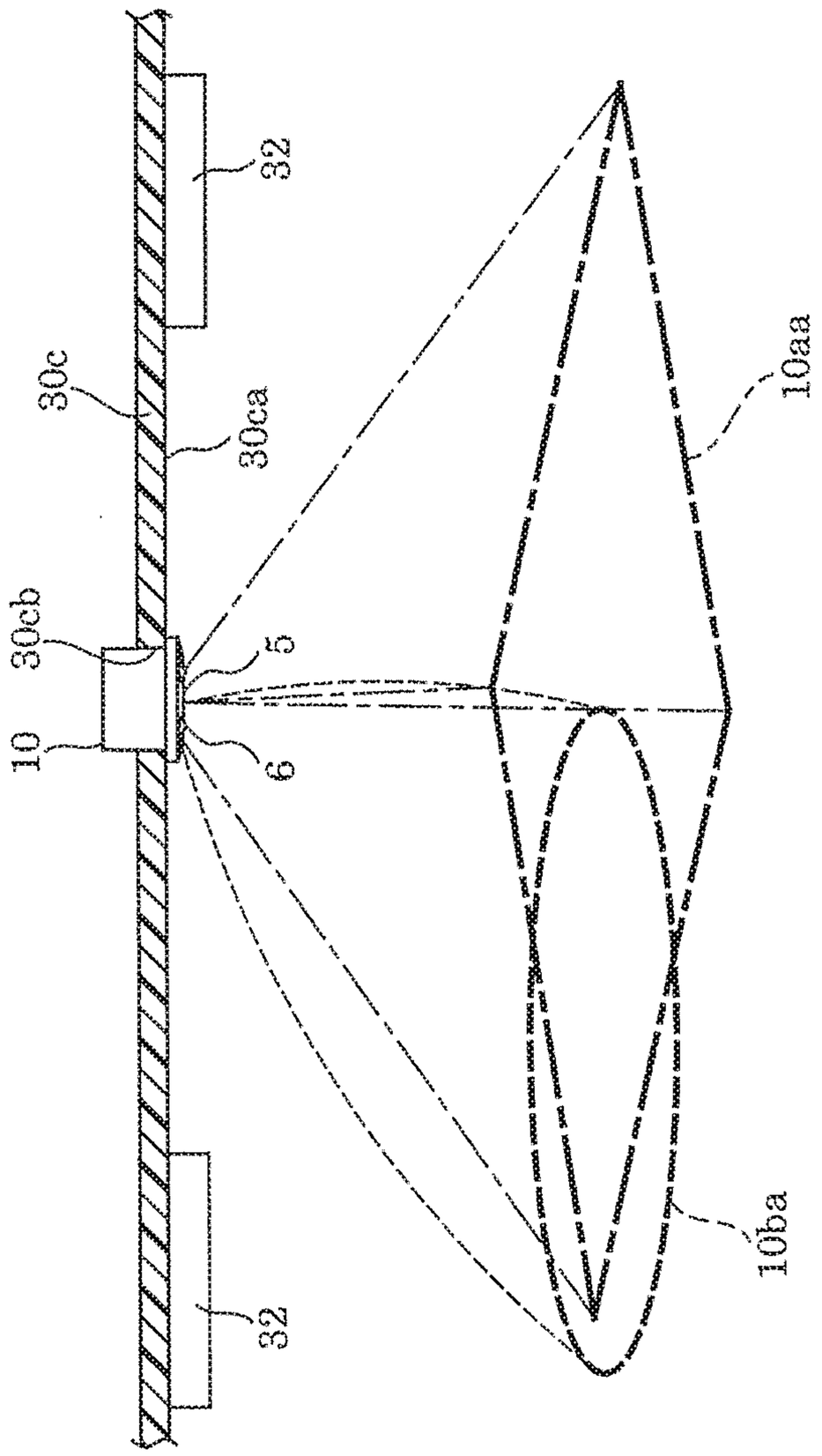


FIG. 5

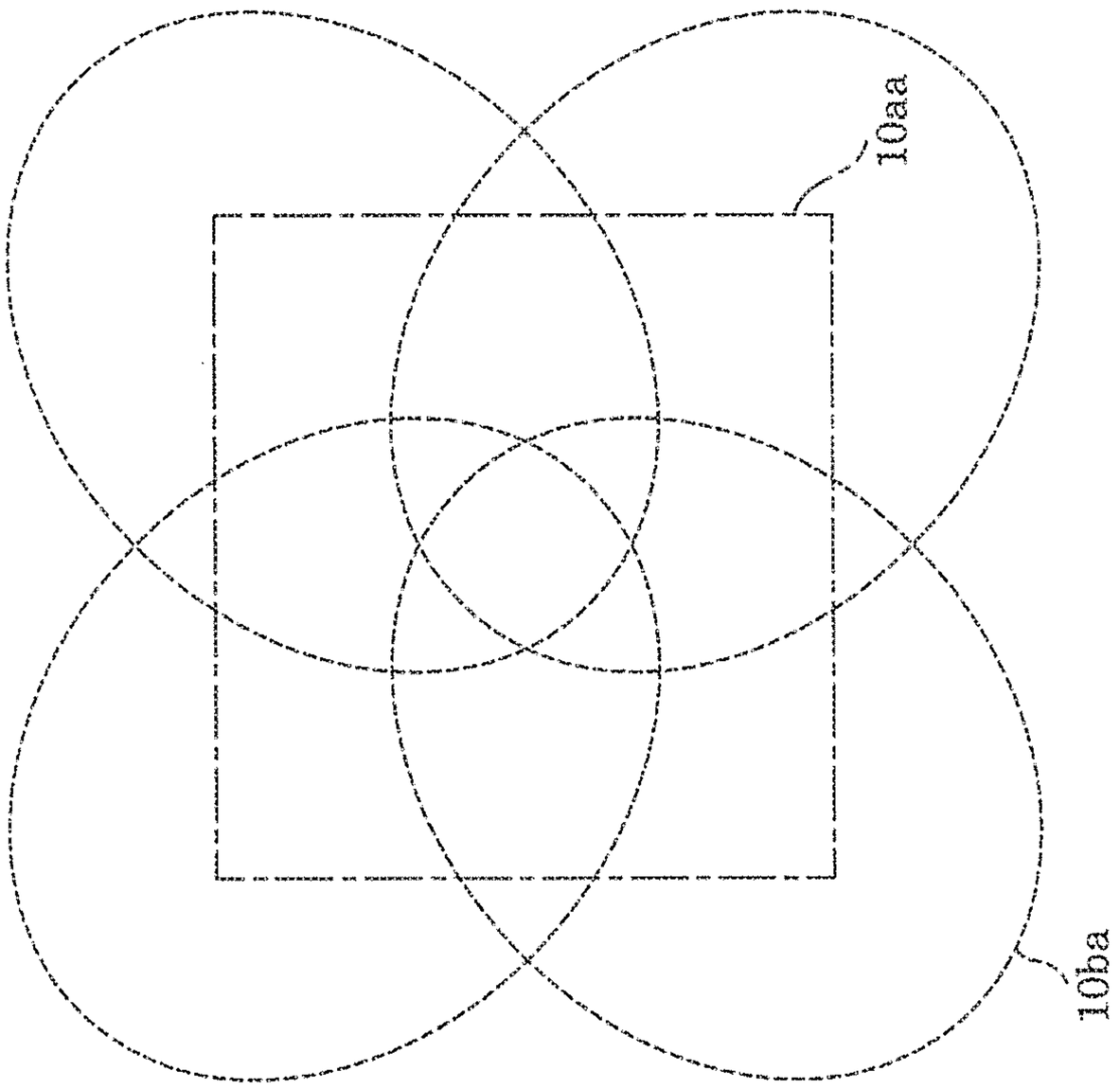


FIG. 6

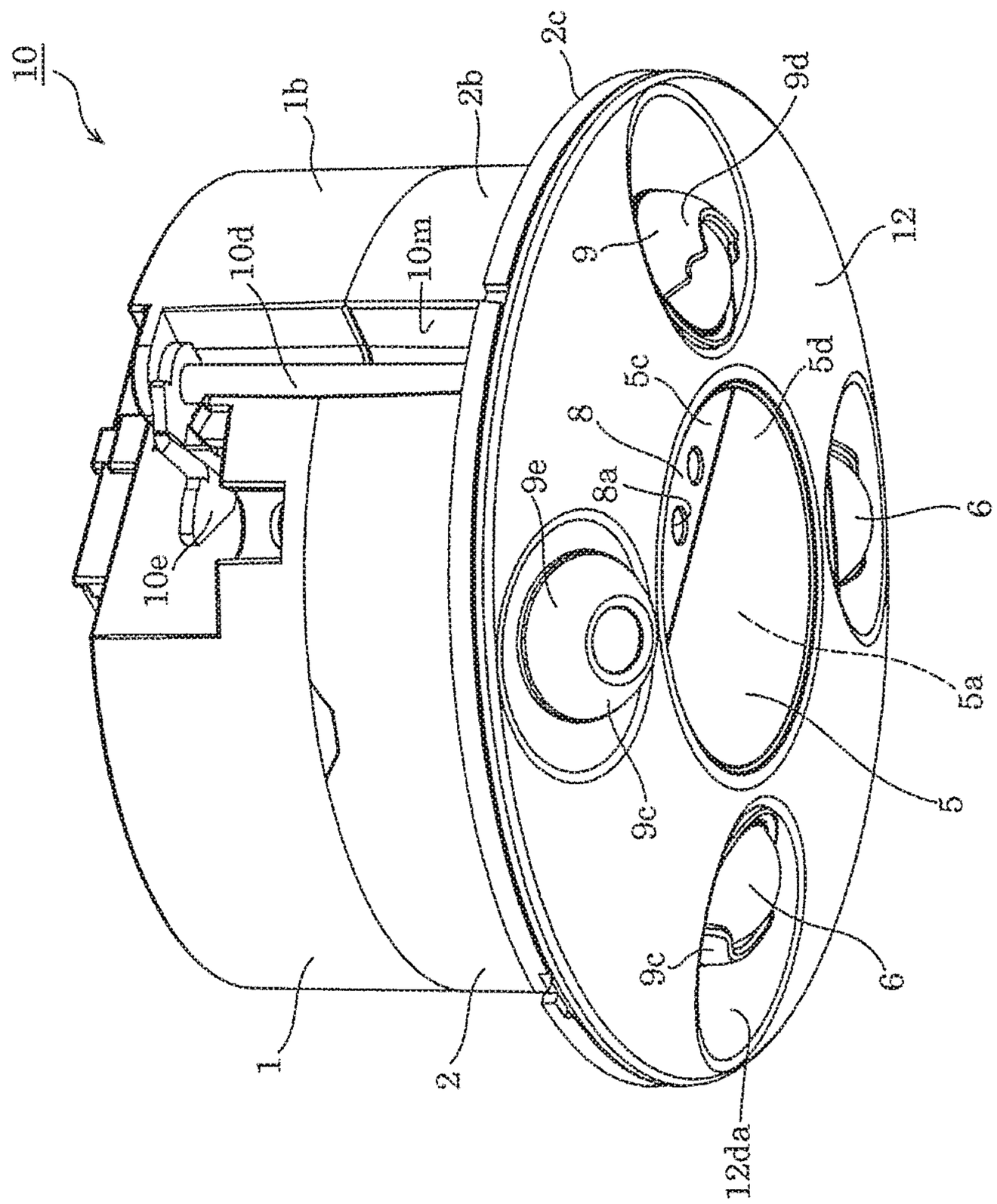


FIG. 7

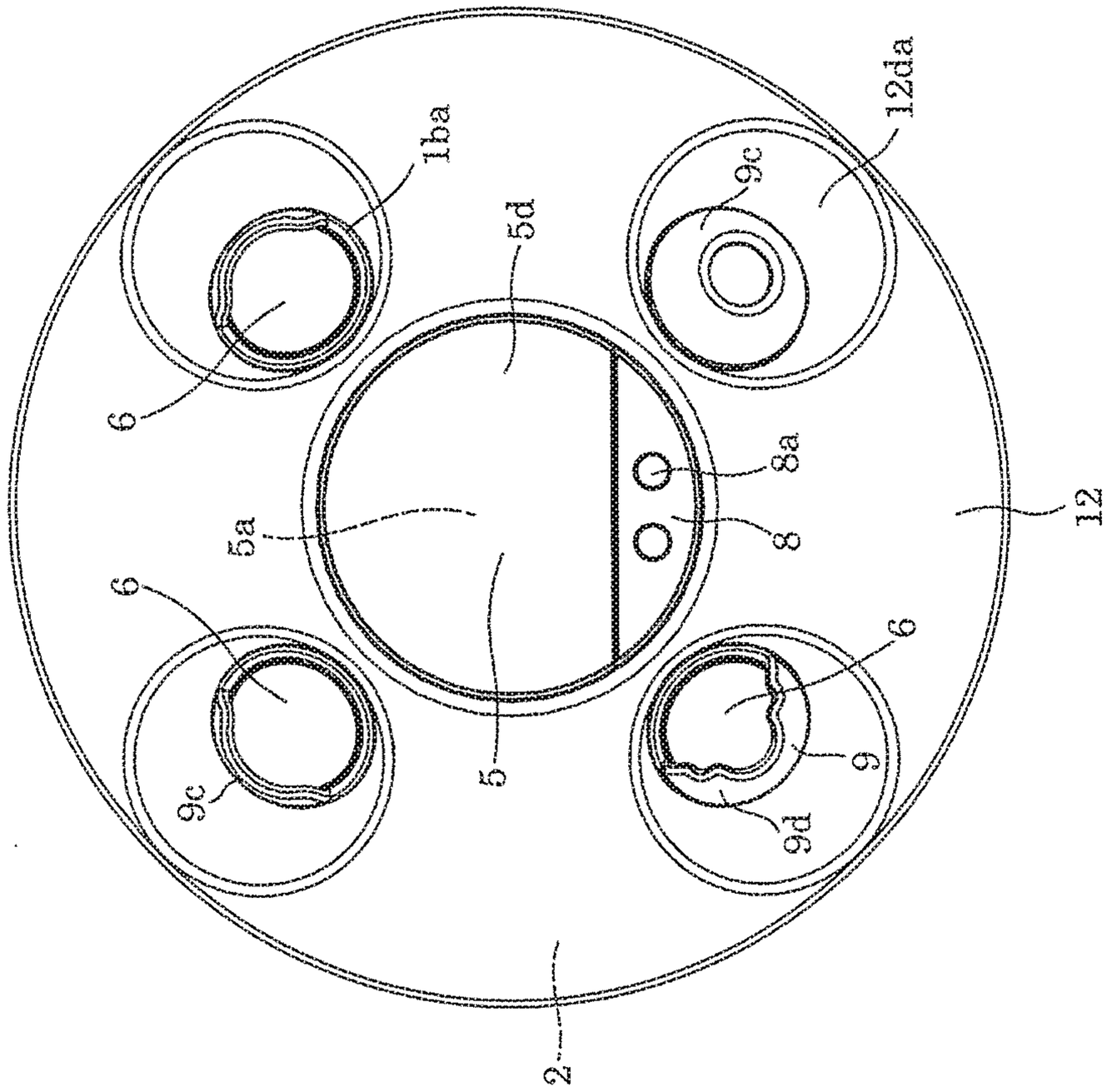


FIG. 8

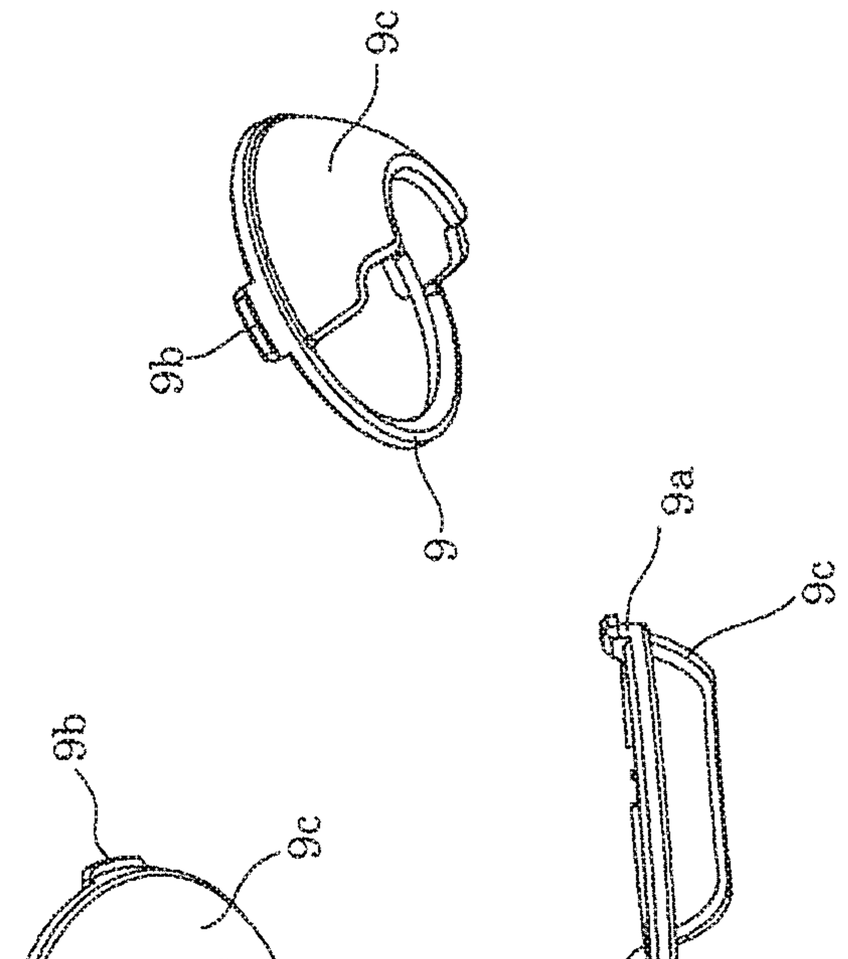


FIG. 9

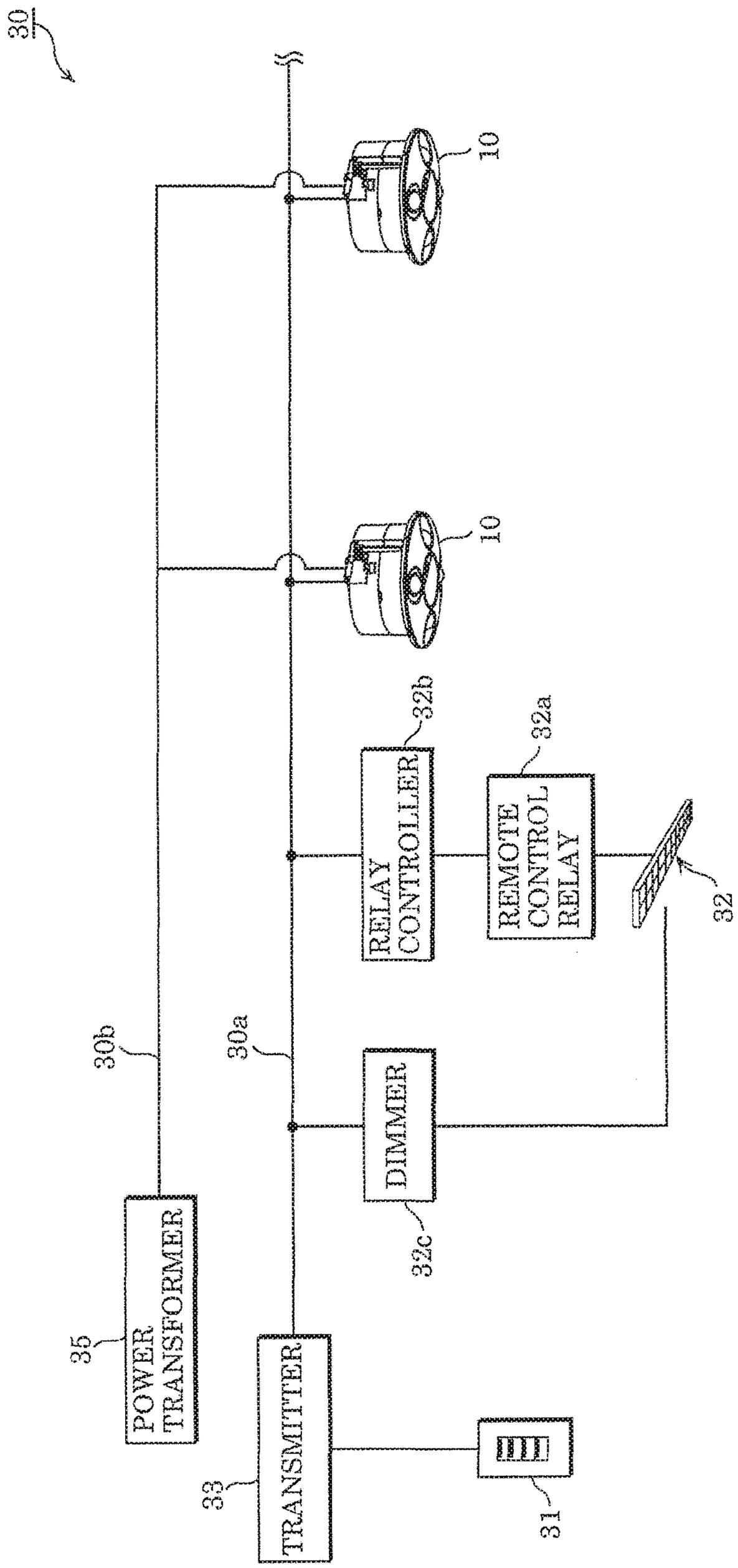
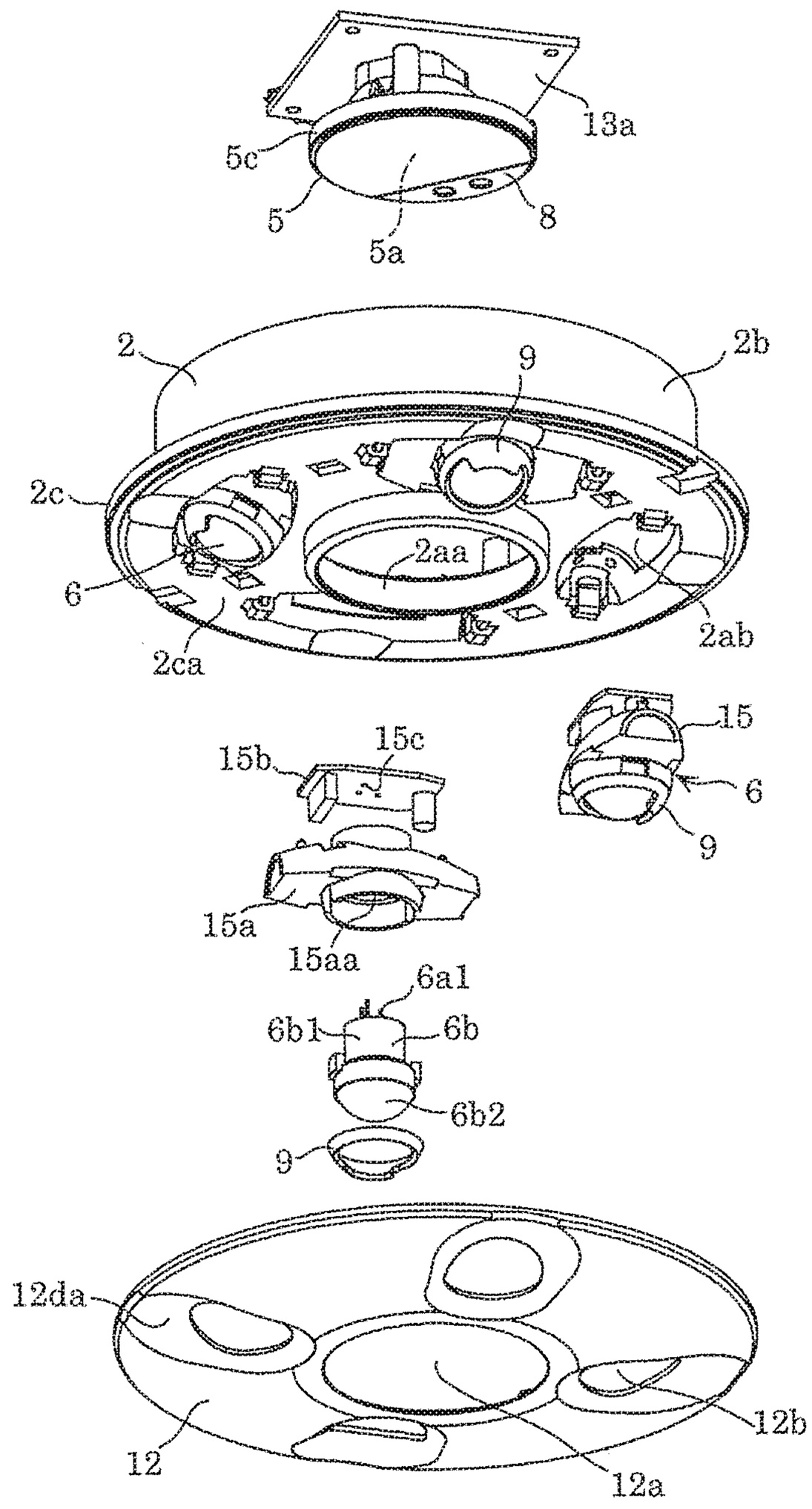

30
10
10
32b
RELAY CONTROLLER
32a
REMOTE CONTROL RELAY
32
30b
30a
DIMMER
32c
35
POWER TRANSFORMER
33
TRANSMITTER
31

FIG. 10


13a
5c
5
8
5a
2
2b
9
2c
2aa
6
2ab
2ca
15
15c
15b
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15a
15aa
6a1
6b1
6b
6b2
9
12da
12b
12
12a

FIG. 11

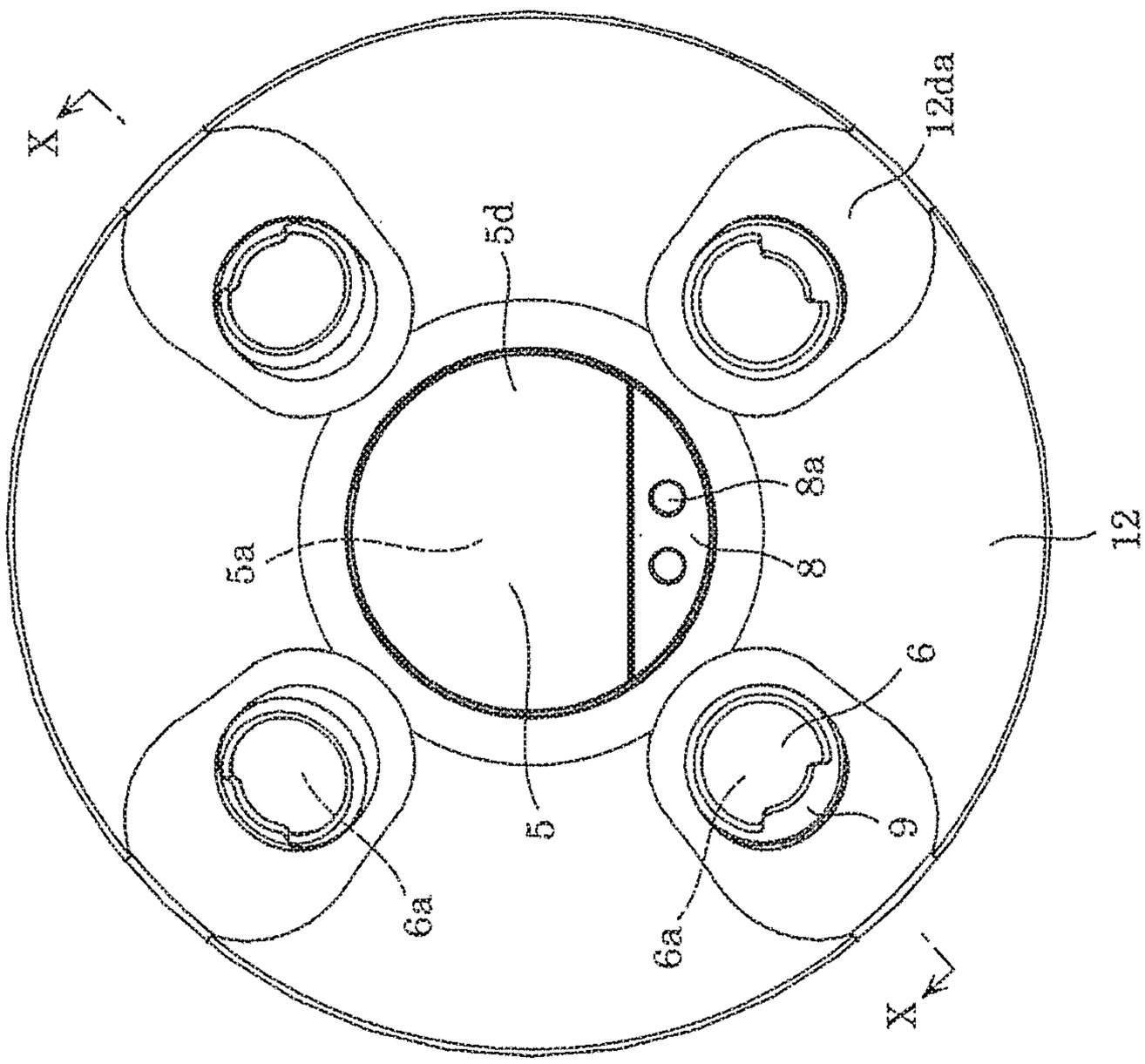
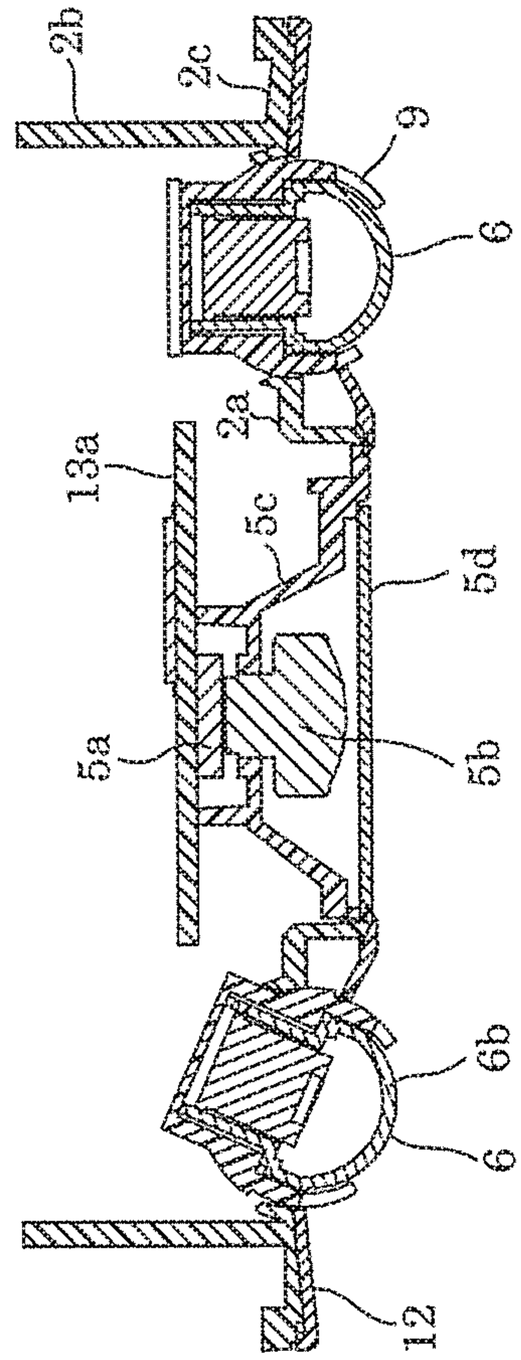


FIG. 12



DETECTION DEVICE, LOAD CONTROL DEVICE, AND LOAD CONTROL SYSTEM

CROSS REFERENCE TO RELATED APPLICATION

This application claims the benefit of priority of Japanese Patent Application Number 2015-051095 filed on Mar. 13, 2015, the entire content of which is hereby incorporated by reference.

BACKGROUND

1. Technical Field

The present disclosure relates to a detection device, a load control device, and a load control system.

2. Description of the Related Art

Conventionally, a load control device has been used, which controls a load device that is a control target, based on a result of detection by a sensor which detects whether a person is present.

A lighting control terminal which includes an imaging element has been known (see Japanese Unexamined Patent Application Publication No. 2013-4311 (Patent Literature 1)).

The lighting control terminal disclosed in Patent Literature 1 determines whether a person is present, based on an image captured by the imaging element, to control dimming of lighting apparatuses. An image capturing range of the imaging element is determined so as to include illumination ranges of the lighting apparatuses. The lighting control terminal divides the captured image into a plurality of regions in correspondence with the illumination ranges of the lighting apparatuses. Upon the detection of a person who has entered the room from the captured image, the lighting control terminal according to Patent Literature 1 controls the dimming of a lighting apparatus for a region where the person is present.

In addition, as a configuration applicable to load control device, a human body detecting device is known (see Japanese Unexamined Patent Application Publication No. 2001-325677 (Patent Literature 2)) which includes a human body detecting sensor which captures an image of motion of a human body and processes the image, and an infrared sensor which operates by thermal sensing.

The human body detecting device according to Patent Literature 2 includes an infrared sensor in addition to a human body detecting sensor so that the infrared sensor which performs detection at a high speed complements a delay in image processing by the human body detecting sensor, thus improving sensing performance.

SUMMARY

There is a demand for a load control device that has a configuration for more accurately detecting a person, and also a demand for further improvement in the configuration since the configurations of the lighting control terminal according to Patent Literature 1 and the human body detecting device according to Patent Literature 2 are insufficient.

The present disclosure provides a detection device which detects a person more accurately, a load control device, and a load control system.

A detection device according to the present disclosure includes: a first sensor which detects, based on a captured image, whether a person is present in a first detection range; a plurality of second sensors which are disposed around the first sensor, and detect, based on infrared radiation, whether a person is present in respective second detection ranges each of which overlaps at least a portion of the first detection range; and at least one hood which blocks part of infrared radiation directed to at least one of the plurality of second sensors, to reduce a non-overlapping portion of a combined detection range of the first detection range of the first sensor and the second detection ranges of the plurality of second sensors, the non-overlapping portion being a portion in which the first detection range and the second detection ranges do not overlap.

Furthermore, a load control device according to the present disclosure includes: the detection device; and a load controller which controls a load, based on a result of detection by the detection device.

Furthermore, a load control system according to the present disclosure includes: the load control device; and a load controlled by the load control device.

The detection device, the load control device, and the load control system according to the present disclosure achieve advantageous effects of increasing the accuracy of detecting a person.

BRIEF DESCRIPTION OF DRAWINGS

The figures depict one or more implementations in accordance with the present teaching, by way of examples only, not by way of limitations. In the figures, like reference numerals refer to the same or similar elements.

FIG. **1** is a perspective view illustrating a load control device according to Embodiment 1;

FIG. **2** is an exploded perspective view illustrating the load control device according to Embodiment 1;

FIG. **3** is a block diagram illustrating the load control device according to Embodiment 1;

FIG. **4** is a perspective view illustrating a first detection range and a second detection range of the load control device according to Embodiment 1;

FIG. **5** is a plan view illustrating the first detection range and the second detection ranges of the load control device according to Embodiment 1;

FIG. **6** is a perspective view illustrating a variation of the load control device according to Embodiment 1;

FIG. **7** is a front view illustrating the variation of the load control device according to Embodiment 1;

FIG. **8** is a perspective view illustrating principal parts of the variation of the load control device according to Embodiment 1;

FIG. **9** is a block diagram illustrating a load control system includes the load control device according to Embodiment 1;

FIG. **10** is a perspective view illustrating a load control device according to Embodiment 2;

FIG. **11** is a plan view illustrating the load control device according to Embodiment 2; and

FIG. **12** is a cross-sectional view illustrating a cross section of a principal portion taken along XX in FIG. **11**.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The following describes embodiments with reference to the drawings. The embodiments described herein are specific examples of the present disclosure. Thus, numerical values, shapes, elements, arrangement and connection of the elements, steps (processes), and the processing order of the steps described in the embodiments below are examples, and

are not intended to limit the present disclosure. Among the elements in the embodiments below, an element which is not described in an independent claim can be added arbitrarily. The sizes and positional relationship of members illustrated in the drawings may be exaggerated in order to provide clear description. In the following description, with regard to the elements included in embodiments, a plurality of elements may be achieved by a single member and that member may serve as the plurality of elements, or the function of one member may be divided and achieved by a plurality of members.

Embodiment 1

The following describes load control device **10** according to the present embodiment, with reference to FIGS. **1** to **5**. A description of load control system **30** which includes load control device **10** according to the present embodiment is given with reference to FIG. **9**.

Load control device **10** according to the present embodiment includes casing **1** and lid **2** as illustrated in FIGS. **1** and **2**. Casing **1** has a cylindrical shape with a closed end. Lid **2** is provided so as to close opening **1***aa* of casing **1**. Lid **2** includes first sensor **5** and second sensors **6**. First sensor **5** is provided in a center portion of lid **2** in plan view. Second sensors **6** are provided along the circumferential portion of lid **2** in plan view. Determiner **3** and communicator **4** illustrated in FIG. **3** are housed in the inner space surrounded by casing **1** and lid **2**. Determiner **3** determines whether a person is present, based on a first sensor signal from first sensor **5** and second sensor signals from second sensors **6**. Communicator **4** transmits a control signal to a control target, based on the result of determination by determiner **3**. First sensor **5** includes imaging element **5***a*. Imaging element **5***a* captures an image of first detection range **10***aa* illustrated in FIGS. **4** and **5**. First sensor **5** detects whether a person is present in first detection range **10***aa*, based on image data generated by imaging element **5***a* through image capturing, and outputs a first sensor signal. Second sensors **6** each include infrared sensor **6***a* which may be referred to as a light receiver. Infrared sensor **6***a* detects infrared radiation in second detection range **10***ba*. Second sensor **6** detects whether a person is present in second detection range **10***ba*, based on the infrared radiation detected by infrared sensor **6***a*, and outputs a second sensor signal. First detection range **10***aa* overlaps second detection ranges **10***ba* of second sensors **6**. Load control device **10** includes hoods **9** which adjust second detection ranges **10***ba* of second sensors **6** by blocking part of infrared radiation directed to second sensors **6** so that first detection range **10***aa* and second detection ranges **10***ba* match.

Load control device **10** according to the present embodiment can detect a person with higher accuracy by including hoods **9** which block part of infrared radiation directed to second sensors **6**.

The first briefly describes the entirety of load control system **30**.

Load control system **30** includes load control devices **10**, switch **31**, lighting apparatuses **32**, transmitter **33**, and power transformer **35**, as illustrated in FIG. **9**. In load control system **30**, plural load control devices **10**, switch **31**, plural lighting apparatuses **32**, and transmitter **33** are electrically connected to one another via transmission line **30***a*. In load control system **30**, power transformer **35** and load control devices **10** are electrically connected to one another via power source line **30***b*.

Switch **31** is configured to control turning on and off and dimming lighting apparatuses **32**. Switch **31** is configured to transmit control signals for turning on and off and dimming lighting apparatuses **32**, via transmitter **33** by multiplexing. Switch **31** can control turning on and off and dimming certain lighting apparatus **32** among plural lighting apparatuses **32**, by transmitting a control signal by multiplexing. The control signal includes address information which identifies lighting apparatus **32** which is to be controlled and control information for controlling lighting apparatus **32**. In other words, load control system **30** is configured to transmit a control signal through two-wire transmission line **30***a* by multiplexing.

Lighting apparatuses **32** each include remote control relay **32***a*, relay control terminal unit **32***b*, and dimming terminal unit **32***c*. In the following, relay control terminal unit **32***b* is referred to as relay controller **32***b*, and dimming terminal unit **32***c* is referred to as dimmer **32***c*. Relay controller **32***b* controls remote control relay **32***a* in response to a control signal from transmitter **33**. Relay controller **32***b* has an address determined for the controller. Relay controller **32***b* controls remote control relay **32***a*, based on the content of a control signal which includes address information indicating the same address as the address predetermined for the controller, among the control signals transmitted by multiplexing. Remote control relay **32***a* includes a contact for switching between on and off of lighting apparatus **32**. Remote control relay **32***a* switches between on and off of lighting apparatus **32**, based on an indication from relay controller **32***b*. Dimmer **32***c* has an address determined for the dimmer. Dimmer **32***c* extracts a control signal which includes address information indicating the same address as the address predetermined for the dimmer, among the control signals transmitted by multiplexing. Dimmer **32***c* controls the dimming of lighting apparatus **32**, based on the content of the control signal. Lighting apparatus **32** functions as a lighting apparatus having a communication function, which includes remote control relay **32***a*, relay controller **32***b*, and dimmer **32***c*.

Transmitter **33** is configured to transmit various control signals to plural lighting apparatuses **32** through two-wire transmission line **30***a*. Transmitter **33** includes a transmission circuit which transmits a control signal. Transmitter **33** is configured to prevent interference of control signals from plural load control devices **10**, and transmit the control signals to lighting apparatuses **32**. Single transmitter **33** is configured to control, by the transmitter itself, 256 circuits of load devices, for example. Power transformer **35** is configured to lower, for example, a voltage of commercial alternating current power to a predetermined voltage, and output the power. Power transformer **35** supplies load control devices **10** with power for driving load control devices **10**. Load control system **30** may include a lighting controller which controls plural lighting apparatuses **32**. The lighting controller turns lighting apparatuses **32** on and off by controlling lighting apparatuses **32** in conjunction with load control devices **10**, for instance.

The following describes basic operation of load control device **10** in load control system **30**.

For example, if load control device **10** determines, based on a first sensor signal from first sensor **5** and a second sensor signal from second sensor **6**, that a person is staying in the detection range of load control device **10** while lighting apparatus **32** is on, load control device **10** maintains lighting apparatus **32** on. If load control device **10** is to maintain certain lighting apparatus **32** on, load control device **10** may output, from communicator **4**, a control

signal for maintaining lighting apparatus **32** on, or may not output a control signal. Load control device **10** outputs, from communicator **4**, a control signal for diming certain lighting apparatus **32** if determiner **3** determines that a person is moving out of the detection range of load control device **10**, based on both a first sensor signal and a second sensor signal. Dimming of lighting apparatus **32** is controlled based on a control signal which includes address information indicating the same address as the address predetermined for dimmer **32***c* of the lighting apparatus. If load control device **10** determines that a person is moving out of the detection range of load control device **10**, load control device **10** dims, for example, certain lighting apparatus **32** in the on state with 100% output to 50% output.

If load control device **10** determines that a person is not present, based on a first sensor signal from first sensor **5** and a second sensor signal from second sensor **6**, for example, load control device **10** outputs, from communicator **4**, a control signal for turning off certain lighting apparatus **32**. Relay controller **32***b* of certain lighting apparatus **32** controls remote control relay **32***a*, based on a control signal which includes address information indicating the same address as the address predetermined for relay controller **32***b*. Remote control relay **32***a* turns off lighting apparatus **32**, based on an indication from relay controller **32***b*. In load control system **30** which includes load control devices **10** according to the present embodiment, a load device which is a control target controlled by load control device **10** is lighting apparatus **32**. Examples of the control target include not only lighting apparatus **32**, but also various load devices such as a ventilation fan and an air conditioner.

The following describes a specific structure of load control device **10**.

Casing **1** of load control device **10** includes a bottom plate and cylinder **1***b*. Casing **1** has a cylindrical shape with a closed end, which is formed by the bottom plate and cylinder **1***b*, as illustrated in FIG. **2**. Lid **2** includes bottom portion **2***a* and cylinder portion **2***b*. Lid **2** has a cylindrical shape with a closed end, which is formed by bottom portion **2***a* and cylinder portion **2***b*. In a state where casing **1** and lid **2** are fitted, load control device **10** forms a box which is hollow inside. Load control device **10** has a cylindrical shape, in a state where casing **1** and lid **2** are fitted. Casing **1** has a pair of through holes **1***ca* in the circumferential portion in plan view. Casing **1** has a structure in which first screws inserted in through holes **1***ca* are tightened in screw holes of lid **2**. Casing **1** can be formed using electrically insulating resin material such as urea resin, for example. Lid **2** can be formed using electrically insulating resin material, such as urea resin, for example. Casing **1** and lid **2** may be formed using the same material or different materials.

Lid **2** has first window hole **2***aa* and second window holes **2***ab*. Lid **2** has one first window hole **2***aa* in the center portion of bottom portion **2***a*. First window hole **2***aa* passes through bottom portion **2***a* in the thickness direction of bottom portion **2***a*. The central axis of first window hole **2***aa* is in the direction perpendicular to outer bottom surface **2***ca* of bottom portion **2***a*. First window hole **2***aa* has a circular shape in plan view. Lid **2** has four second window holes **2***ab* around first window hole **2***aa*. The central axis of second window holes **2***ab* is inclined outward relative to the line perpendicular to outer bottom surface **2***ca* of bottom portion **2***a*. Outer bottom surface **2***ca* of bottom portion **2***a* has depressed portions **2***da* around second window holes **2***ab*, which are stretching outward. Lid **2** has, on the bottom portion **2***a* side, flange portion **2***c* protruding outward from the outer circumference of cylinder portion **2***b*.

Load control device **10** includes plate **12** which covers outer bottom surface **2***ca* of lid **2**. Plate **12** has a circular shape. Plate **12** has first opening **12***a* in the center portion corresponding to first window hole **2***aa*. Plate **12** has second openings **12***b* in the circumferential portion corresponding to second window holes **2***ab*. Plate **12** has a pair of holding grooves **12***f* at the edge of each second opening **12***b*. Each pair of holding grooves **12***f* are formed to hold hood **9** onto plate **12**. Hoods **9** each include base **9***a*, claw portions **9***b*, and shield portion **9***c*. Base **9***a* has a ring shape. The ring shape of base **9***a* is slightly smaller than the external shape of dome portion **6***b***2** in plan view. Claw portions **9***b* are protruding outward from the outer circumference of base **9***a*. A pair of claw portions **9***b* are disposed on base **9***a* being opposed to one another. Shield portion **9***c* is formed protruding from base **9***a* to cover a portion of second sensor **6**. Shield portion **9***c* may be formed so as to block infrared radiation. Hood **9** is formed using resin material, thus allowing claw portions **9***b* and base **9***a* to be elastic. Hood **9** can be attached to plate **12** by deforming claw portions **9***b* and base **9***a* so that claw portions **9***b* are hooked on holding grooves **12***f*. Hood **9** can be detached from plate **12** by deforming claw portions **9***b* and base **9***a* so that claw portions **9***b* are pulled out from holding grooves **12***f*. Plate **12** has hollows **12***da* around second openings **12***b* in the circumferential portion corresponding to depressed portions **2***da*. Plate **12** serves as a face plate of load control device **10**. First sensor **5** of load control device **10** is exposed from first opening **12***a* of plate **12**. Second sensors **6** of load control device **10** are exposed from second openings **12***b* of plate **12**.

First sensor **5** includes lens part **5***b*, lens holder **5***c*, and cover plate **5***d*, in addition to imaging element **5***a*. For example, a solid state imaging element such as a complementary metal oxide semiconductor (CMOS) image sensor or a charge coupled device (CCD) image sensor can be used as imaging element **5***a*. Imaging element **5***a* is configured so as to obtain image data. Lens part **5***b* is provided in front of imaging element **5***a*. Lens part **5***b* includes, for example, a lens which condenses light, and an adjuster which relatively displaces imaging element **5***a* and the lens. The adjuster can be formed using a permanent magnet which holds the lens, and a magnet coil which moves the permanent magnet. Lens part **5***b* moves the lens by adjusting a current flowing through a coil, thus adjusting a focal point with respect to imaging element **5***a*. Lens holder **5***c* holds lens part **5***b*. Lens holder **5***c* has a ring shape. Cover plate **5***d* is provided so as to close third opening **5***c***1** of ring-shaped lens holder **5***c*. Cover plate **5***d* is disposed in front of lens part **5***b*. Cover plate **5***d* is light-transmissive. Cover plate **5***d* is colored, thus making it difficult to see inside of first sensor **5** from the outside. Lens holder **5***c* includes indicator **8** at a portion of the ring shape in plan view. Indicator **8** has at least one light emitting diode **8***a*. Light emitting diode **8***a* shows the operating state of load control device **10**, based on the color of emitted light and the illumination state of the diode.

Second sensors **6** each include sensor cover **6***b*, in addition to infrared sensor **6***a*. Infrared sensor **6***a* has a cylindrical shape. Infrared sensor **6***a* has three terminals **6***a***1** protruding in the axial direction. Sensor cover **6***b* has tube portion **6***b***1** and dome portion **6***b***2**. Tube portion **6***b***1** has a cylindrical shape. Dome portion **6***b***2** covers tube portion **6***b***1**. Dome portion **6***b***2** has a lens which condenses infrared radiation. Tube portion **6***b***1** and dome portion **6***b***2** of sensor cover **6***b* are integrally formed. Sensor cover **6***b* can be formed using polyethylene resin, for example. Sensor cover **6***b* covers infrared sensor **6***a* on the side opposite to terminals **6***a***1**. In second sensor **6**, infrared sensor **6***a* detects,

through sensor cover **6***b*, infrared radiation emitted by a person. In order to secure a predetermined viewing angle, second sensor **6** has sensor cover **6***b* protruding outward relative to outer bottom surface **2***ca* of lid **2**.

Second sensors **6** are mounted on first circuit board **13***a* via lid **2**. FIG. **2** illustrates that second sensors **6** are directly mounted on first circuit board **13***a*, to facilitate a description. First circuit board **13***a* has a disc-like shape in plan view. First circuit board **13***a* includes first insertion holes **13***b* and second insertion holes **13***c*. First insertion holes **13***b* are formed into an arc shape in plan view. First insertion holes **13***b* are each formed to house a part of tube portion **6***b***1** of sensor cover **6***b*. Infrared sensors **6***a* are disposed so as to be partially in contact with first circuit board **13***a*. Terminals **6***a***1** of infrared sensors **6***a* are inserted in second insertion holes **13***c*. First circuit board **13***a* has three second insertion holes **13***c* for each second sensor **6**. Second insertion holes **13***c* are each formed into an oval in plan view. Terminals **6***a***1** are inserted in second insertion holes **13***c*, being inclined relative to first surface **13***aa* of first circuit board **13***a*. First insertion holes **13***b* and second insertion holes **13***c* of first circuit board **13***a* allow infrared sensors **6***a* to be mounted, infrared sensors **6***a* being inclined relative to first surface **13***aa* of first circuit board **13***a*. Infrared sensors **6***a* each have a light-receiving surface for receiving infrared radiation, and an optical axis that is inclined toward the circumference from the center portion of lid **2** in plan view, the optical axis being perpendicular to the light-receiving surface.

On first surface **13***aa* of first circuit board **13***a*, electronic device **5***j* such as a field-programmable gate array (FPGA) is mounted, in addition to imaging element **5***a*, light emitting diode **8***a*, and infrared sensors **6***a*. Mounting components such as an integrated circuit (IC) and a microcomputer are mounted on a second surface of first circuit board **13***a* opposite first surface **13***aa*. Wiring is formed into a predetermined shape on first circuit board **13***a* so as to establish electrical connection with imaging element **5***a*, light emitting diode **8***a*, infrared sensors **6***a*, electronic device **5***j*, and various mounting components. In load control device **10**, determiner **3** and communicator **4** are achieved using electronic device **5***j* and such mounting components. First circuit board **13***a* is fixed to lid **2** with screws.

First circuit board **13***a* is electrically connected with second circuit board **13***f*. Second circuit board **13***f* has a disc-like shape. Various electronic components **13***e* are mounted on second circuit board **13***f*. Examples of electronic components **13***e* include an electrolytic condenser, a photocoupler, a thermo sensitive register, a transistor, a varistor, and a diode. Second circuit board **13***f* forms a direct current-direct current (DC-DC) converter, using various electronic components **13***e* mounted thereon. Second circuit board **13***f* forms a power supply circuit which supplies power to first circuit board **13***a*. Second circuit board **13***f* is fixed to casing **1** with second screw **13***d*. Second circuit board **13***f* includes plural terminals. In load control device **10**, plural terminals are exposed on a side of casing **1** opposite lid **2**. The terminals can function as feed terminals which supply power to load control device **10**. The terminals can function as communication terminals which transmit control signals from communicator **4**.

Load control device **10** includes tightening screw **10***d* and metal clip fitting **10***e*. Tightening screw **10***d* is provided along groove **10***m* along casing **1** and lid **2**. Metal clip fitting **10***e* is formed so as to allow tightening screw **10***d* to be fit in the metal clip fitting. Load control device **10** is attached to installation surface **30***ca* of, for instance, ceiling material **30***c* of a building, as illustrated in FIG. **4**. Load control device **10** is disposed, being embedded in through port **30***cb* provided in ceiling material **30***c*. Flange portion **2***c* is formed so as to be in contact with installation surface **30***ca* in a state where load control device **10** is embedded in through port **30***cb* in ceiling material **30***c*. Flange portion **2***c* and metal clip fitting **10***e* attach load control device **10** into ceiling material **30***c* using tightening screw **10***d* and metal clip fitting **10***e*. Load control device **10** is disposed being attached into ceiling material **30***c* so that first sensor **5** and second sensors **6** detect a space vertically below construction surface **30***ca*.

The following describes the circuit configuration of load control device **10** with reference to FIG. **3**.

Load control device **10** includes power supply **7**, in addition to determiner **3**, communicator **4**, first sensor **5**, and second sensors **6**. Load control device **10** is a detection device which detects whether a person is present, and further controls a load via communicator **4**.

Power supply **7** is achieved by the DC-DC converter formed on second circuit board **13***f*. Power supply **7** is connected to commercial power, for example, and supplies power to determiner **3**, communicator **4**, first sensor **5**, and second sensors **6**.

Determiner **3** includes controller **3***s* and timer **3***t*. Determiner **3** receives a first sensor signal from first sensor **5** and second sensor signals from second sensors **6**. Controller **3***s* is configured to cause communicator **4** to output, based on a first sensor signal and a second sensor signal, a control signal for controlling turning on and off and dimming lighting apparatus **32**. Controller **3***s* can be achieved by, for example, a microcomputer in which a central processing unit (CPU), for instance, is used. Timer **3***t* measures time. Communicator **4** outputs various control signals, based on indications from determiner **3**. Communicator **4** is configured to transmit a control signal by multiplexing.

Controller **3***s* causes communicator **4** to output a control signal for turning off lighting apparatus **32** after a predetermined time period measured by timer **3***t* has elapsed since controller **3***s* has determined that a person is not present, based on a first sensor signal and a second sensor signal. Controller **3***s* resets the counting by timer **3***t* if controller **3***s* determines, based on a first sensor signal and a second sensor signal, that a person is present while timer **3***t* is measuring time. Load control device **10** can maintain lighting apparatus **32** on until timer **3***t* completes decrementing time newly after the counting is reset.

First sensor **5** includes image processor **5***e*, in addition to imaging element **5***a*. Image processor **5***e* includes arithmetic controller **5***f*, first storage **5***g*, and second storage **5***h*. Arithmetic controller **5***f* performs arithmetic processing on image data generated by imaging element **5***a* through image capturing. Arithmetic controller **5***f* is achieved using a FPGA and a digital signal processor (DSP). A semiconductor element which can perform digital image processing at high speed, such as an advanced image processor, may be used for arithmetic controller **5***f*, instead of the DSP.

First storage **5***g* stores image data generated by imaging element **5***a* through image capturing. A mass storage device is used for first storage **5***g* so that high volume image data can be stored. For example, a volatile memory having comparatively large storage capacity such as dynamic random access memory (DRAM) can be used for first storage **5***g*. Second storage **5***h* stores in advance shape data indicating contours of a person viewed from the ceiling material **30***c* side, for instance. Shape data indicating contours of a person is used to perform image discrimination processing for distinguishing between a person and an object other than

a person. Second storage **5***h* is included separately from first storage **5***g*. A non-volatile memory which can transfer shape data at a comparatively high speed, such as synchronous DRAM (SDRAM), is used for second storage **5***h*.

Image processer **5***e* temporarily stores into first storage **5***g* image data generated by imaging element **5***a* through image capturing. Image processer **5***e* reads image data stored in first storage **5***g* into arithmetic controller **5***f*, as appropriate. Image processer **5***e* reads shape data indicating contours of a person from second storage **5***h* into arithmetic controller **5***f*, as appropriate. Arithmetic controller **5***f* performs image differentiation processing on the read image data. In the image differentiation processing, as a difference in the background, a current image based on current image data captured by imaging element **5***a* is compared with a background image based on background data captured in advance by imaging element **5***a* before a person enters first detection range **10***aa*. Background data may be stored in first storage **5***g* or in second storage **5***h*. Arithmetic controller **5***f* compares a current image with a background image, and generates a differential image based on a difference per pixel. In the image differentiation processing, a differential image may be generated based on a temporal difference obtained by comparing two image data that are read by imaging element **5***a* at different times, rather than based on a difference in background. Arithmetic controller **5***f* performs processing for extracting differential pixels from a differential image obtained by comparing a current image with a background image and binarizing luminance values. In the processing for extracting differential pixels, a luminance value of a pixel which does not change between a current image and a background image is below a predetermined threshold. In the processing for extracting differential pixels, if a person is present, there is a change between a current image and a background image. In the processing for extracting differential pixels, a luminance value of a pixel, which changes between a current image and a background image is greater than or equal to a predetermined threshold.

Arithmetic controller **5***f* performs processing for extracting differential pixels, and thereafter performs recognition processing on the differential pixels. In the recognition processing, image discrimination processing by shape pattern recognition for determining how much a shape of a contour formed by a group of the extracted differential pixels matches shape data indicating a contour of a person prestored in second storage **5***h*. Arithmetic controller **5***f* can determine whether the shape of the extracted contour corresponds to a person or not, by determining a percentage at which the shape of the extracted contour matches prestored shape data indicating a contour of a person. Arithmetic controller **5***f* can extract the contour shape using, for example, a Sobel filter, a Prewit filter, or the like, as recognition processing on the differential pixels.

Arithmetic controller **5***f* outputs a first sensor signal indicating that a person is present, upon the detection of presence of a person by image discrimination processing. Each time imaging element **5***a* outputs image data, first sensor **5** compares image data with a background image, thus appropriately detecting whether a person is present. Load control device **10** can detect whether a person is present even if only one person who is not moving is present.

Infrared sensor **6***a* of each of second sensors **6** includes pyroelectric element **6***d* and signal processing circuit **6***e*. Pyroelectric element **6***d* detects infrared radiation emitted by a person. Signal processing circuit **6***e* includes amplifier circuit **6***f*, band-pass filter **6***g*, comparator circuit **6***h*, and output circuit **6***j*. Amplifier circuit **6***f* amplifies a signal from pyroelectric element **6***d*. Band-pass filter **6***g* eliminates an unnecessary frequency component which can result in noise, from the amplified signal. Comparator circuit **6***h* determines whether a signal from which an unnecessary frequency component has been eliminated exceeds a predetermined threshold. If the signal exceeds the predetermined threshold, output circuit **6***j* outputs a second sensor signal indicating that a person is present. Specifically, signal processing circuit **6***e* amplifies a signal from pyroelectric element **6***d*, and compares the amplified signal with the threshold. Infrared sensor **6***a* outputs a second sensor signal via terminals **6***a***1** to determiner **3** if the signal from pyroelectric element **6***d* is greater than the threshold.

Load control device **10** determines whether a person is present, based on a first detection signal from first sensor **5** and second detection signals from second sensors **6**, and controls turning on and off and dimming lighting apparatuses **32** individually. In particular, first sensor **5** detects whether a person is present, based on a difference of image data, and thus load control device **10** can determine whether a person is in first detection range **10***aa* and determine that a person has moved out of first detection range **10***aa*. Load control device **10** can dim lighting apparatus **32** while a person is passing through first detection range **10***aa*, and turns on lighting apparatus **32** only when a person stays in first detection range **10***aa*.

First sensor **5** detects whether a person is present, based on image data generated by imaging element **5***a* through image capturing. First detection range **10***aa* needs to have predetermined brightness to allow imaging element **5***a* of first sensor **5** to obtain image data. Infrared sensors **6***a* detect whether a person is present, based on infrared radiation emitted by a person, and thus second sensors **6** can detect whether a person is present, independently of brightness.

In load control device **10**, first sensor **5** obtains image data at predetermined time intervals. Load control device **10** can detect the brightness around the load control device, using first sensor **5**. First sensor **5** calculates, as ambient brightness, an illuminance from an average value of the entire image data generated by imaging element **5***a* through image capturing. In other words, first sensor **5** also functions as an illuminance sensor. If the brightness detected by first sensor **5** is greater than a predetermined illuminance, determiner **3** determines whether a person is present, based on a first sensor signal and a second sensor signal. A threshold of the predetermined illuminance can be set to 20 1×, for example, although this value depends on image capturing performance of imaging element **5***a*. The threshold of illuminance can be stored in second storage **5***h*, for example.

If the ambient brightness around load control device **10** is less than the predetermined illuminance, determiner **3** determines, based only on a second sensor signal from second sensor **6**, whether a person is present, and causes communicator **4** to output a control signal. Independently of the ambient brightness, load control device **10** may determine, based on a first detection signal and a second detection signal, whether a person is present, and output a control signal from communicator **4**.

The following briefly describes first detection range **10***aa* and second detection ranges **10***ba* of load control device **10** according to the present embodiment.

For example, first detection range **10***aa* is formed in a quadrangular pyramid having first sensor **5** as a vertex, as illustrated in FIG. **4**. Second detection range **10***ba* is formed in an oblique circular cone having second sensor **6** as a vertex. FIG. **4** illustrates second detection range **10***ba* where one of four second sensors **6** detects presence of a person, as

an example. On the floor, first detection range **10***aa* of first sensor **5** is formed in a rectangular shape, as illustrated in FIG. **5**.

Second detection range **10***ba* of second sensor **6** is formed into an oval shape on the floor so as to overlap first detection range **10***aa* of first sensor **5**. First sensor **5** and second sensors **6** are disposed such that the longitudinal direction of each of second detection ranges **10***ba* on the floor is along a diagonal line of first detection range **10***aa* on the floor. Load control device **10** is disposed such that the entirety of four second detection ranges **10***ba* includes first detection range **10***aa* on the floor.

First sensor **5** can be configured to switch between on and off of the detection function of detecting whether a person is present, for each of a plurality of regions into which first detection range **10***aa* is divided. Load control device **10** can turn off, in advance, the detection function in a specific region where detection of presence of a person is not necessary, such as a region where a pillar, for example, is present, depending on where load control device **10** is disposed. First sensor **5** can store the regions into second storage **5***h*. Load control device **10** may have a configuration in which divided regions are appropriately determined from the outside using a remote-control device.

Each of the regions overlaps at least one of second detection ranges **10***ba* of second sensors **6**. When load control device **10** controls, for each of the regions, whether to turn on or off the detection function in the region, load control device **10** turns on or off the detection function in the region which is superposed on at least one of second detection ranges **10***ba* of second sensors **6**. Once load control device **10** turns off the detection function in a region, load control device **10** does not detect a person even if a person is present in the region in which the detection function is off.

In load control device **10**, if a region in which the detection function is off overlaps second detection range **10***ba*, first sensor **5** does not detect whether a person is present, whereas second sensor **6** detects whether a person is present. If the ambient brightness is sufficient, load control device **10** determines whether a person is present, based on a logical product of a first sensor signal and a second sensor signal. If the ambient brightness is greater than the predetermined illuminance, determiner **3** performs signal processing based on a logical product of a first sensor signal and a second sensor signal, thus determining whether a person is present. Yet, determiner **3** does not determine that a person is present even if second sensor **6** detects presence of a person in a region in which the detection function of first sensor **5** is off.

If the ambient brightness is insufficient, load control device **10** determines whether a person present, based on only a second sensor signal from second sensor **6**. For each of regions into which first detection range **10***aa* of first sensor **5** is divided, according to whether the detection function is on or off in the region, controller **3***s* of load control device **10** automatically controls on and off of second sensor **6** which detects presence of a person in second detection range **10***ba* that overlaps the region, when load control device **10** determines regions. If controller **3***s* sets the detection function in a certain region to off, load control device **10** can control and turn off the function of second sensor **6** corresponding to the region in which the detection function is determined to be off. If controller **3***s* sets the detection function in a certain region to off, load control device **10** may turn off second sensor **6** corresponding to the region in which the detection function is set to off, by negating a second sensor signal from second sensor **6**. Thus, load control device **10** may control on and off of second sensor **6** by controlling the power supply to second sensor **6** or by determiner **3** asserting or negating a second sensor signal from second sensor **6**.

Second sensors **6** are provided along the circumferential portion of lid **2** such that first detection range **10***aa* of first sensor **5** and second detection ranges **10***ba* of second sensors **6** overlap. However, first detection range **10***aa* of first sensor **5** is formed in a rectangular shape on the floor, whereas second detection range **10***ba* of each of second sensors **6** is formed in an oval shape on the floor. In load control device **10**, different sensor elements are used for first sensor **5** and second sensors **6**, and thus it is not easy to make first detection range **10***aa* and second detection ranges **10***ba* match. For example, if load control device **10** is disposed in ceiling material **30***c* at 3.0-meter high, a quadrangular pyramid of first detection range **10***aa* of first sensor **5** may have a square bottom surface that is 5.4 meters on each side on the floor. For example, if load control device **10** is disposed in ceiling material **30***c* at 3.0-meter high, second sensors **6** may detect presence of a person within a range where the bottom surfaces of the oblique circular cones of second detection ranges **10***ba* are inscribed in a square that is 9.0 meters on each side on the floor.

In particular, if load control device **10** is attached to, for instance, a slanting ceiling, first detection range **10***aa* and second detection ranges **10***ba* of load control device **10** tend to be significantly different. In load control device **10** according to the present embodiment, second detection ranges **10***ba* of second sensors **6** can be adjusted by attaching hoods **9** such that first detection range **10***aa* and second detection ranges **10***ba* match on the floor.

Hoods **9** of load control device **10** according to the present embodiment are not limited to be each formed to have shield portion **9***c* that is a protruding portion of the perimeter of base **9***a*. As illustrated in FIGS. **6** to **8**, load control device **10** according to a variation of the present embodiment may include hood **9** which has shield portion **9***d* that is a portion of the perimeter of base **9***a* protruding stepwise such that shield portion **9***d* is disposed over sensor cover **6***b*. As illustrated in FIGS. **6** to **8**, load control device **10** according to a variation of the present embodiment may include hood **9** which has shield portion **9***e* that is protruding along the entire perimeter of base **9***a* such that shield portion **9***e* is disposed over sensor cover **6***b*.

Load control device **10** according to the present embodiment may include appropriately shaped hoods **9** which are attached to plate **12** such that first detection range **10***aa* and second detection ranges **10***ba* substantially match on the floor, according to the place where load control device **10** is installed and the detection range of load control device **10**. Load control device **10** according to the present embodiment achieves further increased accuracy of detecting a person by making first detection range **10***aa* and second detection ranges **10***ba* similar, which constitute the detection range of load control device **10**, such that first detection range **10***aa* and second detection ranges **10***ba* substantially match.

Note that load control device **10** illustrated in FIG. **3** may not be achieved as a single device, and may be divided into two devices. In other words, load control device **10** may include two devices, namely, a detection device which detects whether a person is present and a device (referred to as a load controller) which controls a load via communicator **4** according to a detection result. In this case, the detection device may mainly include determiner **3**, first sensor **5**, and

second sensors **6** in FIG. **3**. The load controller may mainly include controller **3***s* and communicator **4** in FIG. **3**.

Furthermore, hoods **9** are provided one for each of second sensors **6**, yet single hood **9** may be provided surrounding second sensors **6**.

Embodiment 2

Instead of the structure of Embodiment 1 in which second sensors **6** are fixed to lid **2**, load control device **10** according to the present embodiment has a structure in which second sensors **6** can be displaced relative to lid **2** as illustrated in FIGS. **10** to **12**, which is a main difference from Embodiment 1. The same numerals are used for equivalent elements as those of Embodiment 1, and a description thereof is omitted as appropriate.

In load control device **10** according to the present embodiment, second sensors **6** are attached to movable parts **15** which displace second sensors **6** relative to lid **2**. Hoods **9** are disposed on movable parts **15**.

In load control device **10** according to the present embodiment, movable parts **15** on which hoods **9** are disposed allow second sensors **6** to displace relative to lid **2**, thus making first detection range **10***aa* and second detection ranges **10***ba* similar, to further increase the accuracy of detecting a person.

Movable parts **15** each have vessel **15***a* and mounting board **15***b*. Vessel **15***a* has a semicircular pillar shape. Vessels **15***a* are each formed to be fitted in second window hole **2***ab* of lid **2**. Each second window hole **2***ab* is formed being depressed in a semicircular pillar shape conforming to the peripheral shape of vessel **15***a* so that vessel **15***a* faces outward relative to the direction perpendicular to outer bottom surface **2***ca* of lid **2**.

Vessel **15***a* has through-hole **15***aa* in a direction perpendicular to the axial direction. Vessel **15***a* is formed such that second sensor **6** can be inserted in through-hole **15***aa*. Mounting board **15***b* has a rectangular plate-like shape. Mounting board **15***b* has third insertion holes **15***c* where terminals **6***a***1** of second sensor **6** are inserted. Mounting board **15***b* is fixed to vessel **15***a* so as to close through-hole **15***aa* of vessel **15***a*. Movable part **15** is mounted at mounting board **15***b* in a state where second sensor **6** is inserted in vessel **15***a* via through-hole **15***aa*. In a state where second sensor **6** is inserted in through-hole **15***aa* of vessel **15***a*, hood **9** is fixed to vessel **15***a* so as to be disposed over sensor cover **6***b*. Vessel **15***a* of movable part **15** can be displaced relative to lid **2** in a state where second sensor **6** is fitted in through-hole **15***aa*, and thus second sensor **6** is movable relative to lid **2**.

In load control device **10**, in order to secure space for allowing movable part **15** to move, first circuit board **13***a* on which first sensor **5** is mounted is smaller in size than first circuit board **13***a* of load control device **10** according to Embodiment 1.

Load control device **10** can adjust second detection ranges **10***ba* where second sensors **6** detect a person, by displacing movable part **15**. Load control device **10** achieves further increased accuracy of detecting a person by adjusting second detection ranges **10***ba* of second sensors **6**. Load control device **10** according to the present embodiment may include hoods **9** each having an appropriate shape different from that of Embodiment 1, as long as second sensors **6** are movable relative to lid **2**. As well as load control device **10** according to Embodiment 1, load control device **10** according to the present embodiment achieves further increased accuracy of detecting a person by making first detection range **10***aa* and second detection ranges **10***ba* similar, which constitute the detection range of load control device **10**, such that first detection range **10***aa* and second detection ranges **10***ba* substantially match.

As described above, the detection device according to an aspect of the present embodiment is a detection device including: a first sensor which detects, based on a captured image, whether a person is present in a first detection range; a plurality of second sensors which are disposed around the first sensor, and detect, based on infrared radiation, whether a person is present in respective second detection ranges each of which overlaps at least a portion of the first detection range; and at least one hood which blocks part of infrared radiation directed to at least one of the plurality of second sensors, to reduce a non-overlapping portion of a combined detection range of the first detection range of the first sensor and the second detection ranges of the plurality of second sensors, the non-overlapping portion being a portion in which the first detection range and the second detection ranges do not overlap.

Here, the at least one hood may be disposed to make a contour formed by the second detection ranges similar to a contour of the first detection range.

Here, the at least one hood may include a plurality of hoods, and the plurality of hoods may be provided one for each of the plurality of second sensors.

Here, the plurality of second sensors may each include a light receiver having a light-receiving surface for receiving infrared radiation, and having an optical axis that is inclined away from the first sensor, the optical axis being perpendicular to the light-receiving surface.

Here, the at least one hood may be detachably attached to the at least one of the plurality of second sensors.

Here, the detection device may further include a casing for disposing the first sensor and the plurality of second sensors, wherein the at least one hood may be detachably attached to the casing.

Here, the detection device may further include a casing for disposing the first sensor and the plurality of second sensors; and a movable part which displaces at least one of the plurality of second sensors relative to the casing.

Here, the at least one hood may be displaced relative to the casing, together with the at least one of the plurality of second sensors.

A load control device according to the present disclosure includes the above detection device; and a load controller which controls a load, based on a result of detection by the detection device.

Furthermore, a load control system according to the present disclosure includes: the above load control device; and a load which is controlled by the load control device.

While the foregoing has described what are considered to be the best mode and/or other examples, it is understood that various modifications may be made therein and that the subject matter disclosed herein may be implemented in various forms and examples, and that they may be applied in numerous applications, only some of which have been described herein. It is intended by the following claims to claim any and all modifications and variations that fall within the true scope of the present teachings.

What is claimed is:

1. A detection device comprising:

a first sensor which detects, based on a captured image, whether a person is present in a first detection range;

a plurality of second sensors which are disposed around the first sensor, and detect, based on infrared radiation emitted by a person, whether a person is present in

respective second detection ranges each of which overlaps at least a portion of the first detection range; and at least one hood which blocks only part of infrared radiation emitted by a person which is directed to at least one of the plurality of second sensors, to reduce a non-overlapping portion of a combined detection range of the first detection range of the first sensor and the second detection ranges of the plurality of second sensors, the non-overlapping portion being a portion in which the first detection range and the second detection ranges do not overlap.

2. The detection device according to claim **1**, wherein the at least one hood is disposed to make a contour formed by the second detection ranges similar to a contour of the first detection range.

3. The detection device according to claim **1**, wherein the at least one hood comprises a plurality of hoods, and the plurality of hoods are provided one for each of the plurality of second sensors.

4. The detection device according to claim **1**, wherein the plurality of second sensors each include a light receiver having a light-receiving surface for receiving infrared radiation, and having an optical axis that is inclined away from the first sensor, the optical axis being perpendicular to the light-receiving surface.

5. The detection device according to claim **1**, wherein the at least one hood is detachably attached to the at least one of the plurality of second sensors.

6. The detection device according to claim **1**, further comprising:

a casing for disposing the first sensor and the plurality of second sensors,

wherein the at least one hood is detachably attached to the casing.

7. The detection device according to claim **1**, further comprising:

a casing for disposing the first sensor and the plurality of second sensors; and

a movable part which displaces at least one of the plurality of second sensors relative to the casing.

8. The detection device according to claim **7**, wherein the at least one hood is displaced relative to the casing, together with the at least one of the plurality of second sensors.

9. A load control device comprising:

the detection device according to claim **1**; and

a load controller which controls a load, based on a result of detection by the detection device.

10. A load control system comprising:

the load control device according to claim **9**; and

the load which is controlled by the load control device.

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